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TUNABLE OPTICAL SOURCES.(U)
JUL 77 R L BYER, S E HARRIS DAAG29-74-C-0033
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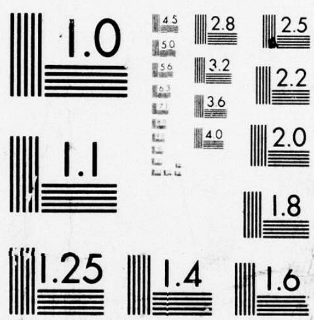

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The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

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Up-converters	Lithium niobates

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Research briefly summarized here has dealt with (1) a tunable coherent spectrometer using a Nd:YAG laser pumped $LiNbO_3$ parametric oscillator, and (2) the development and verification of the theory of resonantly two-photon pumped metal vapor up-converters, and the demonstration of practical devices arising from the theory.

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Edward L. Ginzton Laboratory
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TUNABLE OPTICAL SOURCES

Final Report

for

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A.R.O. Project No. 1T161102BH57-07

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Principal Investigators:

R. L. Byer
S. E. Harris

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I. SCIENTIFIC PERSONNEL

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II. SUMMARY OF RESEARCH FINDINGS

A. Tunable Optical Sources

(S. Brosnan, M. Duncan, R. L. Herbst, and R. L. Byer)

During the period of this program we have carried out research on a tunable coherent spectrometer using a Nd:YAG laser pumped $LiNbO_3$ parametric oscillator. The important milestones in the continuing research effort have been reported in the previous semi-annual reports and are summarized here. During the program period three students have received their Ph.D. degree under Professor R. L. Byer: Richard Begley, Michael Choy, and Robert Fleming.

The important research contributions as a result of this program include:

(1) Growth and perfection of 1.4 and 1.3 $LiNbO_3$ crystals.

(2) Operation of a 1.4 - 4.0 μm tunable $LiNbO_3$ parametric oscillator.

(3) Computer control of the tunable source.

(4) Generation of up to 70 mJ using a parametric amplifier.

(5) Continuous tuning over a 4 - 18 μm range by coherent Raman mixing in H_2 .

(6) High energy diffraction limited unstable resonator source Nd:YAG laser operating at 1 J per pulse 10 pps and 1% efficiency.

(7) Computer interfaced wavelength meter.

Research is continuing on linewidth control of the $LiNbO_3$ parametric oscillator source and on increased conversion efficiency using the $LiNbO_3$ parametric amplifier. Work is also underway to operate the Nd:YAG source in a single axial mode using a programmed Q-switch. Finally, we have recently used the wavelength meter to measure absolute Raman frequencies of H_2 and D_2 and plan to complete the study of this important instrument soon.

B. Applications of Resonantly Two-Photon Pumped IR Up-Converters

(J. H. Newton, J. F. Young, and S. E. Harris)

The major thrust of our work has dealt with the development and verification of the theory of resonantly two-photon pumped metal vapor up-converters and with the demonstration of practical devices arising from the theory. The key to high efficiency is the use of a moderate power pumping laser with an output frequency in two-photon resonance with a non-allowed transition in the metal vapor. This causes a symmetric oscillation of the electron cloud at twice the pump frequency; since the oscillation is symmetric, there is no net dipole moment and, hence, little dispersion or absorption. On the other hand, a resonant enhancement of the third-order nonlinear susceptibilities is produced which drives the sum and difference processes ($\omega_{sum} = 2\omega_{pump} + \omega_{signal}$; $\omega_{diff} = 2\omega_{pump} - \omega_{signal}$) . Using this technique we have demonstrated high resolution, high efficiency IR image up-conversion.

An evaluation[1] of IR imaging technologies sponsored by the Air Force Avionics Laboratory concludes that the overall performance of metal vapor techniques is considerably superior to crystal systems, and is comparable to proposed direct IR detection methods. A particular advantage of the nonlinear techniques is the high instantaneous conversion efficiency achieved. This makes possible time resolved imaging of fast events, a capability notably lacking in direct detection devices which require long integration times. In addition, the relative timing of an illuminating source and the up-converter pump can be used for range-gated imaging. This allows one to determine range and to reduce interference from undesired objects and blackbody background

noise. Other attractive features of these systems include scalability to large apertures and collection angles, high transmission throughout the IR, and the ability to withstand high incident power densities without damage.

Based on the theory developed under this contract,[2] our experimental work has successfully demonstrated a number of these device characteristics. In our initial experiment,[3] single resolution element up-conversion of CO_2 laser radiation was achieved in Na vapor with photon efficiencies as high as 58%, for a power gain of 16. The device employed two-photon resonant pumping of the Na 3s - 3d transition using a tunable source of only 60 μJ energy.

Following this work, we identified a natural two-photon coincidence between the Nd^{+3}:$La_2Be_2O_5$ laser wavelength of 1.079 μm and the Cs $6^2S - 7^2S$ transition, offering the possibility of a simple, practical up-converter system. A theory was developed which showed that the efficiency is inversely proportional to both the two-photon transition linewidth and the pump laser linewidth.[4] Since the two-photon linewidth is subject to self-broadening, the broadening effect had to be determined experimentally[5] before detailed optimization calculations were performed.[4]

We subsequently demonstrated the up-conversion of 2.9 μm images to 4550 Å; a power conversion efficiency of 20% with over 1000 resolvable spots was achieved using a pump power of 8 kW and a Cs density of 2×10^{17} cm^{-4}.[6] The Cs was contained in a 2 mm long side-arm cell with sapphire windows; although window damage per se was not a problem, the sapphire-to-metal seals proved quite unreliable and short lived. Thus extensive optimization and higher Cs densities were not possible initially.

A new cell design was developed using sapphire windows brazed to nickel cups with a nickel-zirconium alloy; the entire cell was enclosed in a small

vacuum chamber to prevent the seals and heaters from oxidizing. Even so we experienced some heater wire failures initially which were solved by using larger wire; the nickel-zirconium seals have held up well.

Using this new design at a Cs density of about 2×10^{17}/cc, images of a metal resolution target were recorded. The diffraction limited resolution for the optical system used was approximately 14 lines/mm, and the recorded images resolved at least 8 lines/mm; approximately 10,000 resolvable spots were up-converted in the field of view. Presently we are measuring the efficiency and resolution as a function of Cs density.

During the program three other up-conversion systems were also evaluated theoretically. The most promising one was the spectrum up-converter. In this device the IR photon is subtracted from (rather than added to) the two pump photons (see Fig. 1); the result should be an extremely broadband (2 μm to 20 μm) up-converter having relatively constant efficiency. Since the non-linear process preserves frequency information, the 2 μm to 20 μm IR spectrum would be translated into the 4249 Å to 5253 Å region, where films and photo-cathodes have high sensitivity. Such a device would enable one to perform IR spectroscopy in the visible; in particular, a complete IR spectrum could be recorded during a single 20 ns laser pulse. For extremely fast events, mode-locked laser pulses could be used. Relative to the image up-converter discussed above, the efficiency will be quite low: photon efficiency of 10^{-6}. However, the sensitivity of visible detectors (i.e., photomultiplier tubes) is on the order of 10^5 times greater than that of good semiconductor IR detectors. Thus, the net sensitivity of the spectrum up-converter would be within an order of magnitude of the sensitivity of semiconductor detectors. But, response times for semiconductor detectors of less than 100 ns are difficult to achieve

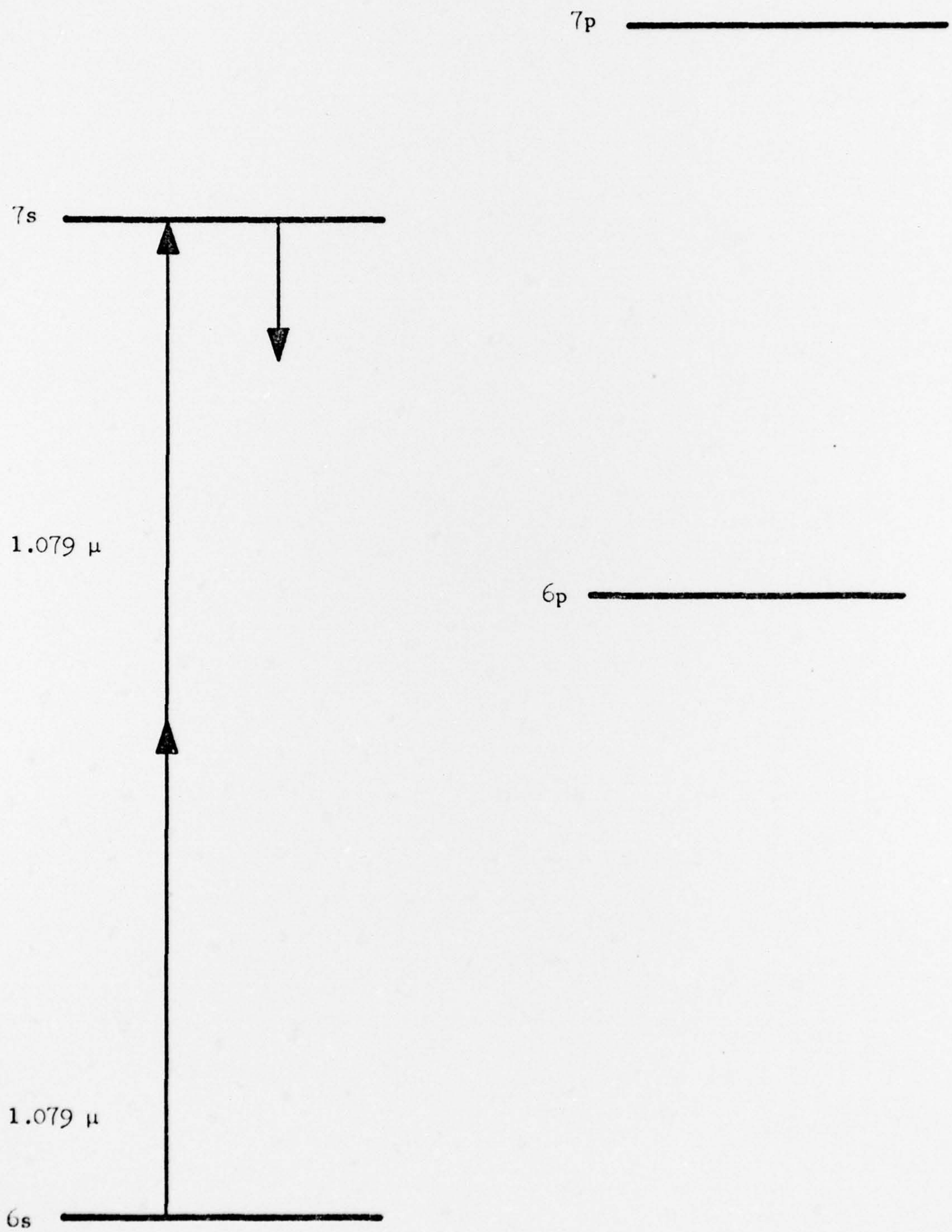

Fig. 1--Two-photon resonant spectrum up-converter.

and usually require liquid helium or liquid nitrogen cooling. Therefore, the spectrum up-converter could prove to be a practical device for recording fast IR events.

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